99E-113

PSP Cover Sheet

Project Title:	Distribution and Status of *Arundo donax* (Giant reed) in the Bay-Delta Watershed
Applicant Name:	Tom Dudley, Research Assoc.
Mailing Address:	Department of Integrative Biology, University of California
	Berkeley, CA 94720-3140
Telephone:	(510) 643-3021
Fax:	(510) 643-6264
E-mail:	tdudley@socrates.berkeley.edu

Amount of funding requested: $ 153,750 for 2 years

Indicate the Topic for which you are applying (check only one box).

- ☐ Fish Passage/Fish Screens
- ☐ Habitat Restoration
- ☐ Local Watershed Stewardship
- ☐ Water Quality
- ☑ Introduced Species
- ☐ Fish Management/Hatchery
- ☐ Environmental Education

Does the proposal address a specified Focused Action? ____ yes ✓ no

What county or counties is the project located in? all (Alameda)

Indicate the geographic area of your proposal (check only one box):

- ☐ Sacramento River Mainstem
- ☐ Sacramento Trib: ____
- ☐ San Joaquin River Mainstem
- ☐ San Joaquin Trib: ____
- ☐ Delta: ____
- ☐ East Side Trib: ____
- ☐ Suisun Marsh and Bay
- ☐ North Bay/South Bay: ____
- ☑ Landscape (entire Bay-Delta watershed)
- ☐ Other: ____

Indicate the primary species which the proposal addresses (check all that apply):

- ☐ San Joaquin and East-side Delta tributaries fall-run chinook salmon
- ☐ Winter-run chinook salmon
- ☐ Late-fall run chinook salmon
- ☐ Delta smelt
- ☐ Splittail
- ☐ Green sturgeon
- ☑ Migratory birds
- ☐ Other: Arundo donax
- ☐ Spring-run chinook salmon
- ☐ Fall-run chinook salmon
- ☐ Longfin smelt
- ☐ Steelhead trout
- ☐ Striped bass
- ☐ All chinook species
- ☑ All anadromous salmonids

ERP strategic objectives:

Goal 5. Prevent establishment of additional non-native invasive species and **reduce the negative biological and economic impacts of established non-native species**

Objective 7. Develop focused control efforts on those introduced species for which control is most feasible and of greatest benefit

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CALFED ECOSYSTEM RESTORATION PROPOSAL

Project Title: Distribution and Status of *Arundo donax* (Giant reed) in the Bay-Delta Watershed

Applicant Name: Tom Dudley, Research Assoc.

Mailing Address: Department of Integrative Biology
University of California
Berkeley, CA 94720-3140

Telephone: (510) 643-3021
Fax: (510) 643-6264
E-mail: tdudley@socrates.berkeley.edu

Amount of funding requested: $153,750 for 2 years

Cooperators:

University of California	Joshua Collins, San Francisco Estuary Inst., Berkeley James Quinn, Info. Center for the Environment, Davis
Federal agencies	Paul Jones, Wetlands Div., USEPA, San Francisco Ray Carruthers, USDA-ARS, Albany
State agencies	Joel Trumbo, Pesticides Div., Fish & Game Deanne DePietro, CERES, CDF&G Kent Nelson, Water Resources
Regional	Richard Dale & Caitlin Cornwall, Sonoma Ecology Center Ann Bryce & Jan Lowry, Cache Creek Conservancy Julie Cunningham, Sacramento River Trust (& CalDWR) Team Arundo del Norte

Organization (Institutional Endorsement Pending):
Regents of the University of California – Sponsored Projects Office

Tax Status: 501 (c) (3) Tax ID#: 946002123

Project Description

This project is fundamentally a mapping program, intended to provide comprehensive information on the extent and local abundances of *Arundo donax* in the Bay-Delta watershed. It builds upon 2 preliminary exercises to determine distribution and abundance of *Arundo* at different spatial scales: the first is an informal geographical assessment by members of Team Arundo del Norte of *Arundo* in the 9-county San Francisco Bay Area downstream of the Sacramento/San Joaquin confluence; the second was tangential to a University of California Water Resources Center-supported ecological study of *Arundo* in which we conducted remote interviews with local resource managers and knowledgeable sources throughout California, in order to provide an initial characterization of the distribution of *Arundo* in the state (Figure 1). While useful in a broad sense to demonstrate the regional scope of invasion by this noxious plant, the very coarse level of detail and unevenness of information sources mean that these data are of limited use in accurately assessing the status of the plant.

The proposed work will address the following information needs:

- Where are current existing populations of *Arundo*, what is its abundance within definable river reaches, and where are problem infestations – reflecting the differences in the spatial resolution applicable in different regions as well as the different mechanisms for information presentation, plant distribution information in the catchments immediately surrounding the Bay will require a greater level of detail than that appropriate for the entire watershed, that is the major river systems and tributaries of the Sacramento and San Joaquin Rivers

- What are the sources of material causing downstream infestations, as dispersal of plants occurs as a result of rhizomes being carried downstream by river flows

- What are the physical characteristics associated with the presence of *Arundo* in river channels, and what factors characterize locations where it is not currently found (such information may suggest environmental factors that could be managed to prevent or reduce infestations)

- What is the role of *Arundo* (and other key invasive riparian plants) in existing and planned restoration sites, and can systems be managed to reduce infestations

The study will be conducted as a set of interlinked Tasks.

Task 1. High density mapping of SF Bay/Delta infestations

The informal geographical surveys for Bay counties (Sonoma, Napa, San Francisco, San Mateo, Alameda and Contra Costa) will be completed and co-ordinated through a single entity (University of California), and these surveys will be extended to the remaining counties (Marin, Solano, Santa Clara) to provide a comprehensive picture of *Arundo* infestations throughout the Bay Area. The surveyor will gather data at every point accessible via existing road systems, a method that has been successful so far in

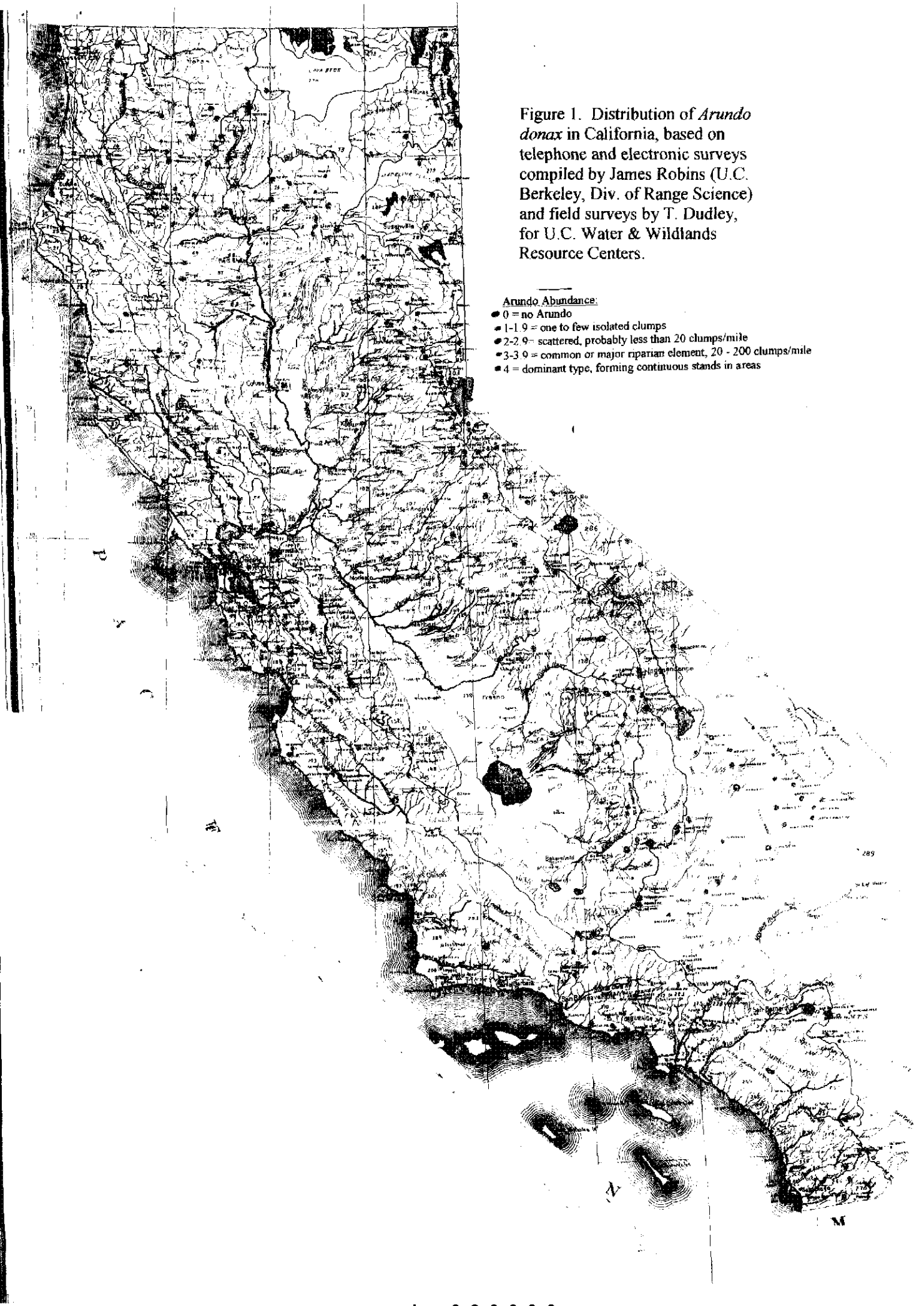

Figure 1. Distribution of *Arundo donax* in California, based on telephone and electronic surveys compiled by James Robins (U.C. Berkeley, Div. of Range Science) and field surveys by T. Dudley, for U.C. Water & Wildlands Resource Centers.

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agriculture and other sources which may explain, in part, noted increases in pest plant abundance. Nitrate concentrations would be measured in surface water at field sites using a nitrate electrode, preferably at baseflow conditions during the growing season (mid-spring through early fall). Environmental and abundance data will be analyzed using multivariate statistical methods to identify factors correlated with relative abundance and performance of plants, in particular to examine whether there are natural or anthropogenic factors (e.g. flood frequency, stream regulation, agricultural run-off, riparian status, etc.) which may show significant relationship with *Arundo* populations. Such analyses may provide strategies to improve control and reduce costs of control, and to suggest where control may not be needed if environmental factors can be managed so as to regulate invasive plant populations below an economic or ecological threshold.

In addition, particular attention will be paid to investigating through interviews and field reconnaissance to identify the uppermost populations which are likely sources of plant material distributed to sites downstream, and where eventual control efforts should be initiated.

This information will be compiled in a database as before, but then incorporated into the ICE California Rivers Assessment basemaps. Where feasible, we will integrate our database with that of the Delta Flood Protection Program (DFPP) being developed by the California Department of Water resources.
[completion date for data acquisition: October 2000; for map production: June 2001]

Task 3. *Arundo* and riparian restoration

The role of invasive species interfering with habitat restoration will be addressed in conjunction with Tasks 1 and 2. In some cases *Arundo* eradication is itself a major goal of a restoration project; in most, degraded habitat is to be restored towards a condition that will better support native species or riparian/wetland habitat is being created as mitigation for impacts elsewhere. In all these situations we will investigate the presence of *Arundo* following restoration efforts, in order to evaluate the risks that it poses to current and future restoration efforts. These sites will be visited during regional sampling work, as well as contact will be made with managers responsible for conducting and/or monitoring the work. We are compiling a list of the relatively small number of restoration projects in which *Arundo* is being controlled; many other restoration projects managers can be contacted through the Noxious Weed Inventory developed by the California Dept. of Food & Agriculture. In these cases we can be relatively assured of the quality of the information about invasive species present at the sites because of the expected high level of knowledge possessed by restoration managers.

Oftentimes local vegetation maps are constructed to support the restoration project, and in most *Arundo* eradication work this is also the case, so we also have an excellent opportunity to acquire data on invasion and re-infection rates. Although this level of mapping is not the intent of the current proposal, it will be a functional element of the eradication work proposed in the companion proposal to CalFed ERP, and extensive information sharing will take place to support planning and monitoring of all these programs throughout the Bay-Delta watershed. This program will provide a standardized platform for consolidation of new data and existing data region-wide.
[Completion date: October 1999]

context of watershed protection plans to promote the recovery of a variety of listed salmonid species and subspecies. Threatened herptiles are likely to benefit from reducing exotic species, including listed species (e.g. red-legged frog, *Rana aurora*, associated with slower side waters) and declining species (e.g.foothill yellow-legged frog, *R. boylei*, western pond turtle, *Clemmys marmorata*).

Regarding benefits to other ecosystem restoration programs, a central goal of our work is to evaluate the potential risks of invasive plant species, particularly *Arundo*, to interfere with current or planned restoration work. As outlined in the proposer's lecture at the 1999 State of the Estuary Conference, there are abundant examples of restoration efforts within the watershed where exotic plants already cause major impacts to 'restored' habitats. The potential for *Arundo* impacts is extremely high, especially since it appears to still be invading epidemically throughout the watershed. It is critical that anticipated riparian restoration projects envisioned in the CalFed Ecosystem Restoration Program take this concern into account, and while the CalFed Program is certainly aware of the *Arundo* problem in the region, there appears to be relatively little consideration of the threats posed to restoration work at this point in the process.

In the ecological context, this project also entails hypotheses regarding the relationship of *Arundo* invasion and environmental parameters. Based on preliminary surveying, we can describe some environmental features associated with infestations, such as lower gradient streams at low-to-moderate elevations, but with broad associations with soils type, water availability and vegetation. To refine these relationships, we will test a variety of hypotheses that may more adequately describe where problems occur (or do not seem to occur), particularly the relationship with flood frequency and intensity, the role of water regulation, the influence of land use and channel modification, the effects of elevated nitrate levels in surface- and groundwater as well as other water quality parameters. These are too complicated to list as detailed hypotheses, but will be tested via multi-variate analyses of environmental and distribution data collected in the project. The results of those analyses may be useful not only in highlighting where control efforts should be located, but also in articulating water and land use management policies that may help reduce the impacts of exotics.

Linkages. The linkages of this distribution and environmental evaluation study are legion. It will serve as a explicit linkage, or extension, of previously-funded Category III CalFed exotic plant mapping programs for tidal marshes (to San Francisco Estuary Institute 1997) with exotic species problems in the watershed. Objective information on the status and extent of each introduced, invasive species of 'special concern' forms an essential base to satisfy the ERP Strategic Objective #7: "Develop focused control efforts on those introduced species for which control is most feasible and of greatest concern." The development of GIS databases for invasive species also effectively links the SFEI Bay-Delta program with the larger regional California River Assessment program (CARA) at U.C. Davis, and the fact that both systems (SFEI EcoAtlas and UC Davis ICEMaps) are technically compatible (ESRI-ArcInfo) strengthens the platform for collaboration.

Furthermore, we hope to integrate our databases with the California Department of Water Resources assessment map for the Delta Flood Protection Program (DFPP), which focuses on streams entering the Delta. Another fundamentally important set of

studies of the ecology of *Arundo* and other invasive species, samples of soil, vegetation, etc. will likely be collected simultaneously in some sites, but are not immediately relevant to this proposed project and are under the auspices of these parallel studies.

We will provide an annual report on the status of this study, but because of the extensive and complex set of data to be collected, the majority of data analysis and interpretation of results will not be completed until the end of the project in Year 2. We will continue to meet on a regular basis as Team Arundo del Norte, with frequent updates concerning status and implications of on-going studies, and this has been a successful forum to providing valuable and diverse peer review.

Local Involvement

Because this project does not involve manipulation of the ecosystem, it is not relevant to notify county agents of the project, other than for their interest and to solicit useful information, and where access to private or closed public lands for observations may be required. Because of the dispersed nature of the project, it is impossible to determine where such notification will be necessary at this time. Contact with local NGO's, particularly those involved in watershed protection, is desirable to the success of information acquisition, and many of these contacts have already been made on an informal basis through our Team Arundo del Norte outreach efforts.

References

Bell, G P. 1997. Ecology and management of *Arundo donax*, and approaches to riparian habitat restoration in southern California. P. 103-113 *In*: Brock, J. H., M. Wade, P. Pysek and D. Green (Eds.), Plant invasions: studies from North America and Europe. Backhuys Publ., Leiden, The Netherlands.

Douthit, S. 1994. *Arundo donax* in the Santa Ana River Basin. Pp. 7-10 In: Jackson, N. et al. *Arundo donax* workshop.

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Dudley, T. and B. Collins. 1995. Biological invasions in California wetlands: the impacts and control of non-indigenous species in natural areas. Pacific Institute for SIDES, Oakland.

Else, J A; Zedler, P. 1996. Dynamics of the flood disturbed zone of a riparian system: Vegetative establishment and resprouting of woody native species and the exotic, *Arundo donax*. Bull. Ecological Society of America 77: 129.

Frandsen, P. and N. Jackson. 1994. The impact of *Arundo donax* on flood control and endangered species. Pp. 13-16 In: Jackson, N. et al. *Arundo donax* workshop.

Grossinger, R., J. Alexander, AN. Cohen and J.N. Collins. 1998. Introduced tidal marsh plants in the San Francisco Estuary. San Francisco Estuary Institute, 41 pp.

Costs

Task	Direct Labor	Direct Salary & Benefits	Indirect Costs	Service Contracts	Supplies Expenses/ Travel	Total Cost
Task 1 Data collection	0	50,000 (25K/yr)	31,500	0	13,000	94,500
Task 1 Data processing	0	0	12,250	20,000	4,500	36,750
Task 2 Data collection	0	(incl. above)			(incl. above)	
Task 2 Data processing	0	0	7,500	15,000	0	22,500
Task 3	0	(incl. above)			(incl. above)	
Task 4	0	(incl. above)				

Salaries

	Co-P.I. – Dudley (25%, 2 yrs)	10,000	10,000
	GRA – Unnamed (50%, 2 yrs)	15,000	15,000
Service Contracts	San Francisco Estuary Institute	10,000	10,000
	Information Center for the Environment		15,000

Supplies & Expenses

Maps	$400	
Nitrate probes & meter	650	
Water quality supplies, equipment	2000	
GPS/datalogger	4000	
Stationery, databooks, etc.	200	
Sample jars, glassware	250	
Computer supplies & software	2500	
Printing, copying (incl. report production)	2000	
Travel Expenses	2500	2500
Communications		
Phone, fax, postage	250	250
Total S & E	14,750	2750
Total (each year)	49,750	52,750
Indirect Costs	24,875	26,375
Total (2 years)	$153,750	

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CURRICULUM VITA (abbreviated): Thomas L. Dudley

Personal:

Department of Integrative Biology
University of California
Berkeley, CA 94720-3140

Education:

B.A.	U.C. Santa Barbara	1975 Environmental Biology
M.S.	Oregon State University	1982 Aquatic Entomology
Ph.D.	U.C. Santa Barbara	1989 Aquatic and Population Biology

Relevant Experience:

Research Associate, Dept. of Integrative Biology, U.C. Berkeley; Invasion and control of giant reed in California riparian areas (Calif. Water Res. Cent). 7/96-6/98.

Lecturer, Environmental Sciences Program, Univ. of Calif., Berkeley; Co-ordinate Senior Research Seminar. 8/96-present.

Research Associate, Marine Science Inst., U.C. Santa Barbara; Livestock impacts and restoration of Sierra Nevada sub-alpine riparian areas (U.S. Forest Service). 7/93-6/96.

Senior Research Associate, Pacific Institute; Western water policy, ecosystem management and conservation of aquatic biodiversity; Pacific Institute, Oakland, CA. 10/92-3/95.

Consulting Researcher, Calif. Dept. of Parks & Recreation/U.C. Berkeley; Tamarisk invasion in Anza-Borrego State Park; Survey and management plan for aquatic habitats. 5/92-2/96.

Faculty Research Associate, Co-P.I.; Zoology Dept., Arizona State Univ.; Ecosystem consequences of trophic structure in a desert stream; (Nat'l. Science Found.). 8/89-6/92.

Research Assoc.; Marine Science Institute and Biological Sciences Dept., UCSB; Community ecology of southern California streams (N.S.F. & Water Resources Center). 8/85-6/89.

Biological Consultant, Aquatic Biology – stream and estuary impacts, biodiversity assessment; Dames & Moore, Inc., A.D. Little, U.S.E.P.A., Calif. RWQCB-Lohanton, etc.

Relevant Publications (34 total):

Wilzbach, P., T.L. Dudley and J.D. Hall. 1983. Recovery patterns in stream communities impacted by the Mt. St. Helens eruption. Tech. Rept. A-059-ORE, Water Res. Res. Inst., Corvallis, OR.

Cooper, S.D., T.L. Dudley and N. Hemphill. 1986. The biology of chaparral streams in southern California. p. 139-152 in J. DeVries (ed.). Proc. Chap. Ecosystem Research Conf. Report No. 62, Calif. Water Resources Cent., Davis, CA.

Appendix I.

***ARUNDO* SAMPLING PROTOCOL** Directions on back [optional info is in brackets]
questions/info: tdudley@socrates.berkeley.edu; 510-643-3021

DATE _____
SURVEYOR (include contact info): _____
_____

LOCATION

USGS Quad. name and Scale _____ Site number _____

Site name _____ County _____

Location _____ Jurisdiction _____

[Co-ordinates, GPS locations] _____

SITE DESCRIPTION

Habitat type _____ Length of site visible _____

Floodplain width _____ Channel width _____ Stream width _____

Gradient _____ [Elevation] _____ [Stream order] _____

Channel form _____ Substrate _____

Hydrology _____ Channel structures _____

Surrounding land-use:

Space for cross-section profile

Riparian corridor width _____
Riparian vegetation composition (incl. other exotic spp.):

Hydro-geomorphic setting:

***ARUNDO* STAND DESCRIPTION** (circle appropriate choices)

Abundance*: 0 1 2 3 4 Approx. # of clumps at site _____

Ave. max clump height: <6 ft 6-12 12-18 >18 ft Ave. distance betw clumps _____

Growing in: Sun Shade Species forming shade _____ Canopy ht. _____

Vigor: Bright green Mature/faded green Yellowing Browned Dead

Branching: None 10% of stems (sparse) 50+% (common)

Reproduction evidence:

* See key (back) for category descriptions. If abundance category is 2 or less, you may want to use extra datasheets to characterize individual clumps, including plant height, circumference or length/width of clump, stem density, and details of each habitat/geomorphic setting.

Other pertinent environmental information (incl. control or mgt. activities):

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Appendix II.

Task 4. Non-indigenous wetland and riparian species of the Watershed

This Task is not specifically part of our *Arundo* distribution project, but is a component of the larger goal of understanding the broad spectrum of invasive riparian species in the Bay-Delta watershed, which may be of interest to the CalFed ERP. Because information will be developed along with the other data gathering efforts, and much of our current work draws from the original report described below, it is included here as an allied Task. It is our intent to request support funds at a later date for carrying out this Task.

Through interviews and site visits we will gather and collate data regarding distribution and habitat associations of all non-indigenous plant species that could be considered problematic for resource managers. This task is intended to correct, update and expand coverage of a prior statewide evaluation of invasive wetland and riparian species ('Biological invasions in California wetlands: The impacts and control of non-indigenous species in natural areas', Dudley and Collins 1995). In that report we surveyed managers of 52 protected areas representing the bioregions of the State, and categorized the status of and risks associated with 72 plant taxa (68 found within the Bay-Delta watershed) and 70 exotic animals (61 in the watershed). We intend to provide a more complete and comprehensive coverage of areas in the watershed that are protected as natural areas or managed for resource values which are potentially threatened by invasive species. At this point we would focus upon invasive plants in order to integrate watershed data with invasive plant data for tidal wetlands and with California Dept. of Agriculture assessments of aquatic plants in the Delta (e.g. Eichhornia, Egeria, Hydrilla, Lythrum, etc. being investigated by L. Anderson and D. Spencer), and animals could be incorporated at another stage of the project. Much of this information can be gathered simultaneously with the work covered in Tasks 1 and 2.

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ARUNDO SAMPLING PROTOCOL (the Windshield Survey)

The goal of this sampling effort is to determine the general characteristics of plant growth and habitats, including factors which may promote or inhibit *Arundo* spread, and resources at risk. The distributional information will be catalogued into a regional/statewide mapping program to provide a comprehensive picture of the status of *Arundo* invasion, and a baseline to assess management efforts.

The protocol form includes general information useful for the larger effort; you can modify this to create your own working data-sheet if there is additional information useful to you. We typically seek accessible riparian or wetland sites, often where a road crosses a stream, and take notes at the site. For a single stream with multiple access points, one might keep a single data sheet for general information, and then use extra sheets for information at specific sites. Keep in mind that some populations occur well away from wetland edges and are worth noting, esp. since they may be the planted material source for invasive material downslope. It is useful to have a topo map or other detailed map in hand and referenced to the data sheets. Please transmit a copy of your data to us at the address below so they can be incorporated into the statewide effort.

Following are some instructions regarding certain details of the protocol:

Location – road crossings, nearby landmarks, other siting info.

Jurisdiction – who owns and/or manages the sites (also local organization concerned with site)

Habitat type – river, stream, intermittent stream, pond, ditch, garden, etc.

Length of site – meters (or other measure) or habitat observed, to establish density per stream length

Gradient – may be estimated as qualitative steepness of stream, or expressed as % slope if possible

Widths – approx. distance across Floodplain (whole valley width); Channel (from recognizable bank to bank, the standard riparian zone); Stream (ave. width of the actual water)

Channel form – e.g. downcut, wide channel bottom, vertical or broad banks; could draw x-section

Substrate – dominant sediment in channel: silt, sand, cobble, bedrock, wood, etc.

Hydrology – upstream dams, diversions, free-flow, spring-fed, agric. drains, etc.

Channel structures – physical elements that may promote *Arundo* (bridges, rip-rap, etc.)

Surrounding land-use – agriculture (type), residential, industrial, wildlands, forest, etc.

Riparian corridor width – how far vegetation extends on each bank from stream and bank edge

Riparian vegetation composition – major riparian trees, approx. abundance, understory plants, other exotic species present, other notes regarding riparian condition

Hydro-geomorphic setting – where are clumps? in stream, sandbars, inside or outside meander bends, on terraces, base or top of bank, hillslopes, adjacent to structures like bridges, etc.

Abundance – estimated abundance in ecosystem segments (somewhat arbitrary), possibly delineated as the reach accessible or visible from each sampling station (Habitat length)

Categories: 0 = absent (we have to keep track of where it's NOT also)
1 = one to few isolated clumps
2 = scattered, probably less that 20 clumps/mile or 5/100 meters
3 = common or major riparian element, 20 – 200 clumps/mile or 50/100m
4 = dominant type, forming continuous stands in areas

Reproduction evidence – note presence of flowering stalks, whether they are new or last year's stalks, new culms emerging from ground, new clumps, etc.

Space is left at the bottom for any additional notes that you may deem relevant to the presence of *Arundo*. This space may also be used to draw a cross-sectional profile of the channel or site to indicate the typical locations of *Arundo* plants at the sites.

Please contact me with questions about protocol or other aspects of *Arundo* biology and mapping. Send datasheet copies to: Tom Dudley, Dept. Integrative Biology, U. of Calif., Berkeley, CA 94720-3140; tdudley@socrates.berkeley.edu; phone: 510-643-3021; fax: 510-643-6264.

Odion, D.C., T.L. Dudley and C.M. D'Antonio. 1988. Cattle grazing in S.E. Sierran meadows: Ecosystem change and prospects for recovery. p. 277-292 in C.A. Hall and V. Doyle-Jones (eds). Natural History of the White-Inyo Range, Symp. Vol. 2, White Mt. Research Stat., Bishop, CA.

Leland, H.V., S.V. Fend, T.L. Dudley and J.L. Carter. 1989. The effects of copper on species composition of benthic insects in a Sierra Nevada, California stream. Freshw. Biol. 21:163-179.

Dudley, T.L. 1989. Interactions among algae, invertebrates and the physical environment in stream riffle communities. Dissertation, University of California, Santa Barbara. 229 p.

Dudley, T.L. and C.M. D'Antonio. 1991. The effects of substrate texture, grazing and disturbance on macroalgal establishment in stream riffles. Ecology 72: 297-309.

D'Antonio, C.M. and T.L. Dudley. 1993. The influences of exotic species on native communities and ecosystems. Pacific Discovery 46: 8-11.

Dudley, T.L. & N.B. Grimm. 1994. A possible role of an introduced grass in modifying macrophyte resistance and post-disturbance succession in a desert stream. Verh. Int. Ver. Limn. 25:1456-1460.

Dudley, T. and B. Collins. 1995. Biological invasions in California wetlands: the impacts and control of non-indigenous species in natural areas. Pacific Institute for Studies in Development, Environment, and Security, Oakland.

Dudley, T. and M. Embury. 1995. Non-indigenous species in Wilderness Areas: the status and impacts of livestock and game species in designated wilderness in California. Pacific Inst. for SIDES, Oakland.

D'Antonio, C.M. and T.L. Dudley. 1995. Biological invasions as agents of change on islands vs. mainlands. In: Vitousek, P., L. Loope & H. Mooney (eds.) Islands: biodiversity and ecosystem function. Springer-Verlaug.

Sarr, D.A., R.K. Knapp, T.L. Dudley, D.C. Odion, K.R. Matthews & J. Owens. Livestock grazing impacts and the potential for riparian meadow recovery in the Golden Trout Wilderness Area, California. Final Report, U.S. Forest Service, Leopold Institute, Missoula, MT.

D'Antonio, C.M., M.M. Mack and T.L. Dudley. Biological invasions and disturbance. In: L. Walker (ed.), Ecosystems of disturbed ground. Elsevier Press (in press).

Dudley, T.L. *Arundo donax*. 1999. In: Bossard, C., J. Randall and M. Hoshovsky (eds), Wildland weeds of California. (in press).

Zimmerman, P., T. Dudley and A. Herrera. 1998. Growth dynamics of *Arundo donax* in relation to soil texture, moisture, nutrients and shading. Proceedings, Calif. Exotic Pest Plant Council, Concord.

Herrera, A. and T. Dudley. Invertebrate community reduction in response to *Arundo donax* invasion at Sonoma Creek. Submitted to Biological Invasions.

Project Costs. Costs will not be assigned specifically to insuring accomplishment of project; assurance and quality control will be maintained through regular information exchange and feedback among collaborators. The Indirect Costs rate for the University of California is 50%, and covers costs of office and equipment maintenance, and administration of grant activities. It is possible to negotiate Indirect Costs, as a substantial portion of the project will take place 'off-campus', and may qualify for non-campus rates. A detailed quarterly budget will be prepared and provided when feasible.

Schedule. Completion dates for each task are provided within the Project Description. Salary will be paid monthly according to standard campus administrative policy, and payment schedules to the University of California would be negotiated according to standard policy.

Cost-Sharing

Other funds to be committed to mapping of Arundo and other invasive plants:

EPA Wetlands Grant to CDF&G (Lead Joel Trumbo)	$12,000
EPA to support SFEI Goals Project	$20,000

These funds are approved and committed to SFEI to support invasive species mapping in the watershed. Additional shared costs will be associated with companion projects submitted by Team Arundo del Norte and by U.S. Dept. of Agriculture, ARS; please refer to specific proposals for details.

Applicant Qualifications

The applicant (T. Dudley) has been conducting studies of the ecology and impacts of non-native species in western streams and riparian areas since 1990, focusing on *Arundo donax*, Tamarix spp., and Cynodon dactylon (bermudagrass). He has been involved in riparian restoration since 1982, particularly the role of vegetation in recovery of montane meadows damaged by livestock grazing. His research has concerned the dynamics of stream communities and ecosystems since 1977, and he is currently a Research Associate and Lecturer at U.C. Berkeley. In addition, he is the Science & Technical Issues leader for Team Arundo del Norte and the northern California contact for the statewide Teams *Arundo* network, a member of the Board of Directors of the California Exotic Pest Plant Council, and serves on the monitoring review panel for the CalFed Ecosystems Restoration Program. (curriculum vita is included)

Responsibilities of major collaborating participants (SFEI, ICE) are described in Project Description. Other collaborating partners will not be under salary contract, and the collaboration is via information sharing and evaluation.

I-020043

Herrera, A.M. 1997. Invertebrate community reduction in response to *Arundo donax* invasion at Sonoma Creek. P. 87-98 *In*: Dudley, T., J. Reynolds and M Poteet (eds.), The science and policy of environmental impacts and recovery. Envir. Sciences Annual Report, U.C Berkeley.

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linkages will be with local, sub-watershed based mapping programs. Our regional mapping will be conducted in co-operation with the continuing efforts of Team Arundo del Norte to identify sites and carry out *Arundo* eradication in several sites in the region, which is being proposed for CalFed funding as part of this same PSP, and site information exchange will be fully bi-directional. Locally, the Sonoma Ecology Center (TAdN lead agent) has already developed GIS maps of infestations in the Sonoma Creek watershed that conform to this proposed mapping protocol, and both the protocols and the resulting maps will be shared routinely with other TAdN partners that are not explicitly linked to the Team Arundo CalFed ERP projects, such as the Cache Creek Conservancy and the Sacramento River efforts (contact Julie Cunningham, CalDWR).

Technical Feasibility and Timing

Because this project requires no construction or other form of disturbance, no environmental compliance documents, protocols nor permits are required. A discussion of alternatives to this project is also not relevant to the work proposed.

Monitoring and Data Collection Methodology

Ecological Objectives. Despite this being primarily a research project, the data collected will themselves provide a baseline dataset for assessing or monitoring major *Arundo* population changes in the future. Unfortunately, it is beyond the scope of the project to provide the intensive detail necessary for unambiguous evidence of minor (but important) changes, but our information will provide a starting point for local restoration personnel to develop the types of maps needed for such an evaluation. This will be the case in the eradication work that we, through Team Arundo, are proposing. At this time, we are not developing plans for future monitoring to take advantage of the baseline information we generate, but that is a likely option as part of the larger Team Arundo program.

In undertaking an extensive data collection approach such as we are proposing, there is always the risk that it will not be possible to differentiate patterns responsible for *Arundo* invasion, although we will certainly have objective characterization of the conditions where it does occur, and a comprehensive picture of the extent of that invasion. Such information is essential in determining where active management is needed, and how to plan this work.

Monitoring Parameters and Data Collection Approach. Research methods have been described in earlier components of this proposal, and our basic protocol for information organization is provided in Appendix 1. We propose only a single visit to any site as part of the project, and timing and duration will depend upon the site needs in each river system.

Data Evaluation Approach. We do not anticipate collecting physical samples from the field as part of this project other than limited water samples for water quality assessment, and will rely primarily on observation and field measurement data along with existing data collected via other remote means. Because we are involved in a variety of other

Ecological Benefits

Objectives. The primary benefit of this proposed mapping work will be to provide a comprehensive understanding of the scope of *Arundo donax* infestation in the Bay-Delta region and watershed. This information will be made available through electronic and published media to the public and to managers responsible for resource protection within the watershed. With this information, managers can more effectively direct efforts to reduce the impacts posed by *Arundo* infestation, and we will be able to identify those ecosystems that are not presently heavily infested but are at risk to future invasion. By documenting the status of certain aquatic invasive species in the Bay and Delta, e.g. *Spartina* spp. and *Lepidium latifolium* (Grossinger et al. 1998) or *Egeria densa, Eichhornia crassipes, Lythrum salicaria*, etc. (California Dept. of Food & Agriculture Weed Research and Information Center), it has been possible to make rational plans for control. This is NOT the case for other invasive species that are associated with riparian areas in the Delta and watershed, such as *Arundo, Tamarix* spp., *Delairea odorata* (Cape ivy) and many others for which we have limited or very coarse resolution information on their status and habitat associations (Dudley and Collins 1995, Bossard et al. in press), despite the potential for much greater impact to native species and ecosystem function.

The threats posed by *Arundo* invasion and the benefits of eradication projects are detailed in the CalFed companion proposal to this one, '*Arundo donax* Eradication: A project of Team Arundo del Norte' (TAdN; lead organization, Sonoma Ecology Center), but a summary of its environmental impacts and potential beneficiaries of eradication is useful here.

Arundo donax (Giant reed) is a perennial grass native to the Indian sub-continent that has invaded extensive portions of the already threatened wetland and riparian habitats of California, particularly in the southern part of the state (Dudley 1999, Bell 1997). *Arundo* reproduces only vegetatively, and propagules, primarily rhizomes, are carried downstream during flooding events (Else and Zedler 1996). It forms dense stands up to 8 meters tall which are purported to displace native riparian species and create unsuitable habitat for a variety of sensitive aquatic and riparian wildlife species (Bell 1997), including insects upon which many wildlife species depend (Herrera 1997). Because these dense stands are highly flammable, they often convert riparian areas from firebreaks into fire hazards (Scott 1994, K. Gaffney, unpub. data). Additionally, it is indicated that *Arundo* both reduces groundwater because of its high transpiration rates (Iverson 1994) and changes channel morphology by retaining sediments and constricting flow. Their shallow rhizomes provide little structural integrity to streambanks, resulting in undercutting and subsequent bank slumping. In the evaluation of biological invasions of California wetlands Dudley and Collins (1995) identified *Arundo* as one of the major problem species degrading riparian areas in the state, and the California Exotic Plant Pest Council (CalEPPC) included it as one of the top 5 species of concern.

In southern California, *Arundo* dominates the riparian vegetation of numerous river systems, such that some avian taxa are forced to use these poorer resources (*Arundo* along with *Tamarix*/saltcedar) for roosting and foraging because it is the primary vegetation available (J. Greaves, pers. comm.). In northern California we have the advantage that *Arundo* is common, but does not yet dominate most riparian systems, so relatively small control and restoration efforts may forestall the utterly devastating level of invasion that has changed the nature of rivers to the south. In-stream fauna will also benefit from *Arundo* eradication, including both steelhead trout and coho salmon, as *Arundo* alters both the physico-chemical nature of the stream channel and the quality and timing of organic material inputs from litter that forms part of the trophic base for juvenile salmonids. This is a vital concern in the

locating over 150 populations in Alameda and Contra Costa Counties alone (most of which do not pose serious threats). At each access point GPS equipment will be used to establish spatial co-ordinates, regardless of presence or absence of *Arundo*, and a standardized set of data will be attributed to that location to characterize the nature and abundance of any *Arundo* present within a standard stream reach length, geomorphic features, associated ecosystem and land use traits, and other relevant information (see Appendix 1).

A relational database will be constructed which includes survey locations from the GPS co-ordinates or from 1:24,000 scale USGS topographical maps and the associated environmental information, and these data will be incorporated into the basemaps for the SF Bay EcoAtlas developed by our collaborators at the San Francisco Estuary Institute (SFEI). This is a detailed inventory of historic and current resources of tidal areas of the region, involving ESRI-ArcInfo geographical information system technology (GIS). SFEI recently completed a survey and evaluation of invasive plants inhabiting tidal marshes of the Estuary (Grossinger et al. 1998), and current goals are to expand coverage to surrounding watersheds; *Arundo* was included in the tidal zone map and identified as a Potential Species of Concern because of its presence at the brackish margins of the Estuary and on Delta levees. It will be a key invasive exotic species linking the tidelands with the network of tributaries entering the Bay/Delta. The database will remain part of the EcoAtlas inventory system, and printed maps showing areas of infestation will be produced for distribution as well as being accessible to the public through the SFEI Website.

[completion date for data acquisition: December 1999; for map production: July 2000]

Task 2. Extensive, low density mapping of Sacramento/San Joaquin watershed

The same basic data collection protocol will be used to document the presence and abundance categories of *Arundo* in major streams and tributaries of this larger region. Locations will be established according to 1:100,000 maps or possibly greater to reflect the larger geographic scale of this component of the study. The standardized protocol (Appendix 1) has been made available to co-operators of Team Arundo del Norte. However, the difficulty in applying uniform standards to such dispersed data collection approaches, and the absence of experienced informants in much of the watershed, make it necessary to undertake site visits throughout the region in order to validate and augment data gathered by informants. It is impossible to sample at the same geographic density as in Task 1, so we will focus attention on major stream and river reaches and attempt to provide relatively equal levels of sampling intensity throughout the watershed.

This extensive coverage will allow sampling of a wider variety of environmental circumstances, increasing the range of data values which will increase the likelihood of identifying patterns in *Arundo* distribution. Environmental data will be collected both in the field (abundance, geomorphology, associated species, etc. as before), from existing maps (elevation, gradient, soils, land use) and from other available sources (discharge patterns from USGS station data, water quality and nutrient data from EPA databases, and depth to groundwater where data are available). Nutrient data are important because we have shown a preliminary correlation between surface water nitrate concentration and *Arundo* abundance statewide, and our greenhouse studies indicate surprisingly strong responses to nitrate addition, suggesting a possible linkage between enrichment from

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Executive Summary

The invasion of California wetlands and waterways by non-indigenous species of plants and animals poses a serious threat to the ecological integrity of these ecosystems, as has been clearly acknowledged by the CalFed Program, Strategic Plan ERP Goal #5, to "... reduce the negative biological and economic impacts of established non-native species". Of particular concern is *Arundo donax*, commonly known as Giant reed, which was introduced into California from Eurasia in the previous century and is now listed by the California Exotic Pest Plant Council as one of the top 5 problem species in the State. Despite increasing awareness of this problem, the precise distribution and abundance of *Arundo*, and the mechanisms by which it invades and displaces native riparian communities, are poorly known, especially in the central and northern part of the State where population expansion appears to be continuing at a rapid pace.

To manage species invasions effectively, it is necessary to accurately assess where the pest species is, how much there is, and what areas are at risk for infestation. Such information has been carefully compiled for selected invasive plant species in the tidal reaches of the Bay-Delta, but the distributions of many explosive species that inhabit Bay-Delta margins, and riparian areas in the watersheds, have received surprising little documentation. This project is intended to provide an objective evaluation of the extent and magnitude of invasion of riparian areas throughout the entire drainage network of the Bay-Delta by *Arundo donax*. It complements an effort proposed to the CalFed Ecosystem Restoration Program by Team Arundo del Norte to undertake a series of *Arundo* eradication projects in numerous locations in the watershed, and to develop guidelines for conducting such work for use by regional watershed protection groups. In this context, there is a need to develop a better understanding of the geographic scope of the *Arundo* invasion problem, of the factors that promote or that may inhibit its expansion in river systems, and to determine where control efforts are most critically needed. As riparian restoration projects are proposed throughout the Bay-Delta watershed, we particularly need to understand whether and where *Arundo* (along with other invasive riparian plants) will interfere with the restoration process and potentially overwhelm the programs that are being proposed, and subsequently to incorporate such information into restoration planning.

We will build upon preliminary distribution information developed through interviews with resource managers in the region, and through informal surveys in the Bay Area counties. Because knowledge of the situation is limited and uneven, new remote information gathering will be supplemented by field surveys to fill in the many information gaps, and to collect data on ecosystem attributes that are associated with the presence of *Arundo*. The data gathered will then be incorporated into publicly-accessible, digital resource databases at two regional spatial scales, the San Francisco Bay Area via the EcoAtlas being developed through the San Francisco Estuary Institute, and the California Rivers Assessment (CARA) program of the Information Center for the Environment (ICE) based at U.C. Davis.

A nested task will involve assessing through interviews and site visits the presence, and invasive potential, of *Arundo* and other key invasive plant species in completed, current and planned riparian restoration sites in the region.

Indicate the type of applicant (check only one box):

☐ State agency	☐ Federal agency
☐ Public/Non-profit joint venture	☐ Non-profit
☐ Local government/district	☐ Private party
☑ University	☐ Other: _____

Indicate the type of project (check only one box):

☐ Planning	☐ Implementation
☐ Monitoring	☐ Education
☑ Research	

By signing below, the applicant declares the following:

1.) The truthfulness of all representations in their proposal;

2.) The individual signing the form is entitled to submit the application on behalf of the applicant (if the applicant is an entity or organization); and

3.) The person submitting the application has read and understood the conflict of interest and confidentiality discussion in the PSP (Section 2.4) and waives any and all rights to privacy and confidentiality of the proposal on behalf of the applicant, to the extent as provided in the Section.

Thomas L. Dudley

Printed name of applicant

Signature of applicant